

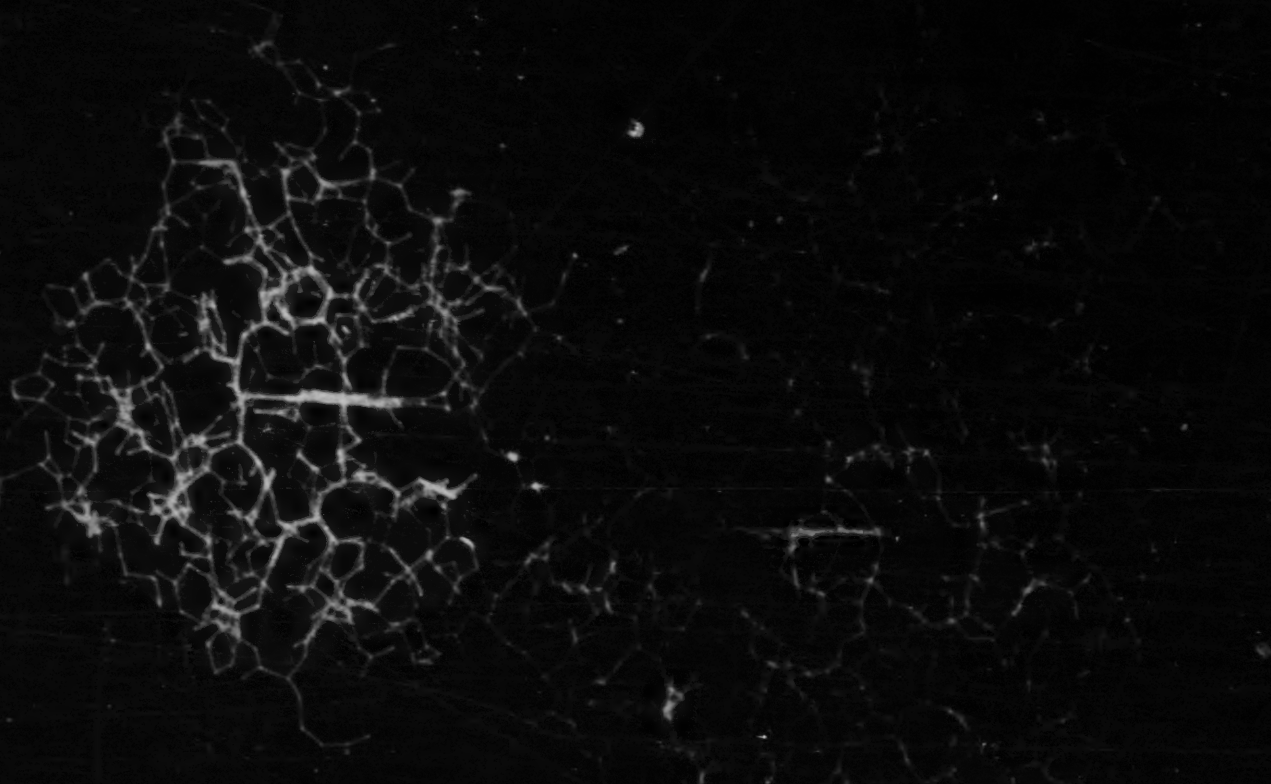
Top 100 chemical producers
Page 9

MAY 4, 1987

A1250-1
5/7/87

CHEMICAL & ENGINEERING

NEWS



Biological Electron Transfer

Researchers explore factors
that govern rates Page 19

0511179C097 9 K AR6518SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

News of the Week

■ UN report on ecological awareness calls for new era of economic growth, offers agenda for future based on concept of sustainability. **Page 4**

■ Although first field tests of genetically engineered bacteria to clear all state and federal hurdles have been conducted, they may not ease the way for future tests. **Page 5**

■ U.S. output of specialty chemicals packaged in aerosol containers rose 4.7% in 1986, the fourth straight year of real growth. **Page 5**

■ Investor Harold Simmons offers to purchase NL Industries' chemical unit for \$732 million. **Page 6**

■ Several chemists are among new members elected by National Academy of Sciences. **Page 6**

Cover: Computer graphics-generated model of yeast cytochrome *c*-yeast cytochrome *c* peroxidase complex. The structure was calculated by V. R. Lum, Life Sciences Research Labs, Eastman Kodak Co.

Letters **2**

Editor's Page **3**

Concentrates

Business **7**

Government **15**

Science/Technology **18**

The Departments

Meetings **28**

Newscrips **48**

Business

Most of 100 largest U.S. chemical producers posted higher sales and increased operating profits in 1986. **Page 9**

Government

Reduced 1988 R&D funding for federal agencies is one of several proposals being considered by Congress. **Page 16**

Science

Although the rise in atmospheric methane has been firmly established, pinning down the causes poses difficult problems. **Page 22**

Newly discovered bacterium secretes cellulase enzyme system that exhibits activity and stability above 70 °C. **Page 23**

Education

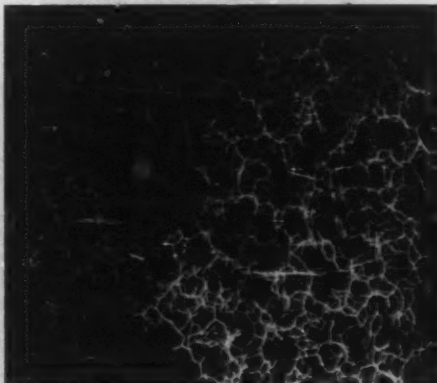
More diversity in graduate program urged for doctorate in analytical chemistry. **Page 25**

Technology

Capabilities of molecular modeling systems increased by introduction of new hardware and software. **Page 26**

Use of ion implantation to raise conductivity of polymers may lead to improvements in current semiconductor materials. **Page 27**

High-temperature membrane to separate gases prepared by in-situ polymerization of polydimethylsiloxane in a porous glass. **Page 27**



Cover Story

Understanding of biological electron transfer enhanced by research to clarify distance dependence of electron transfer rates, and effects of donor-acceptor separation and energetics of reaction. **Page 19**

Sales, Profits Increase for Most Top 100 Chemical Producers

Of 100 largest companies, 58 posted higher sales and 53 increased profits in 1986; restructuring accounted for many of the shifts in ranking

William J. Storck, C&EN New York

C&EN's ranking of the 100 largest chemical producers in the U.S., based on 1986 chemical sales, reflects the improving performance of the chemical industry last year, compared with 1985. The industry's sales increased slightly as many of its major markets firmed, and chemical prices started to move up, although just slightly, from a long-standing plateau. Among the Top 100 chemical producers, in fact, the only consistently poor results in 1986 were for those companies with large stakes in agricultural chemicals, which were pulled down by the beleaguered farm economy.

Of the Top 100 chemical producers, the ranking for which is compiled from corporate annual reports and interviews with companies not issuing annual reports, 58 posted increases in chemical sales for 1986, and 41 registered declines. One company, Huntsman Chemical, was newly formed in 1986, thus no comparison is possible with the year before. The 41 instances of sales declines may seem like a large percentage, but it is a marked improvement over 1985's ranking, when 54 of the Top 100 posted decreases in chemical sales.

The number of companies with larger chemical sales in 1986 was fairly evenly divided between the 50 larger firms on the list and the 50 smaller companies. Of the 50 larger ones, 30 had sales increases, and

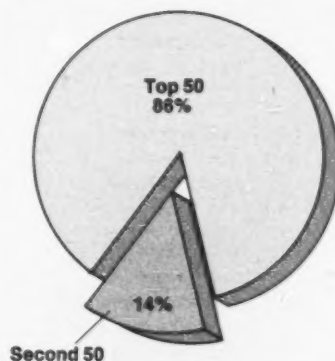
of the smaller producers, 28 had increases.

Operating profits for the Top 100 also improved last year, compared with 1985. Of the 82 companies that reported operating profits, 53 posted increases and 23 posted declines. Four of the firms registered deficits for the year, thus change in operating profits is not figured for them. In the 1985 ranking, 50 of the companies that reported operating profits posted declines from the year before.

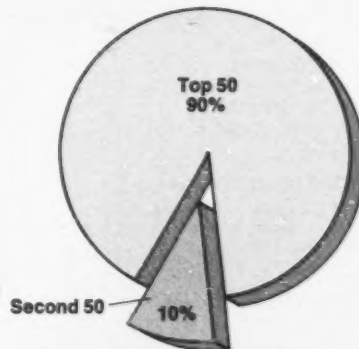
Of the 43 of the 50 larger firms that reported operating profits for 1986, 35 had increases. Of the 39 of the 50 smaller firms that reported operating profits, just 18 had increases. Within this group, however, are a number of fertilizer producers whose earnings are not buffered by other, more profitable products.

Within the 100 firms, very few remained at the same ranking as the previous year. Even among the 10 largest companies, there were changes as firms bought, sold, and

Large firms dominate both sales and earnings...

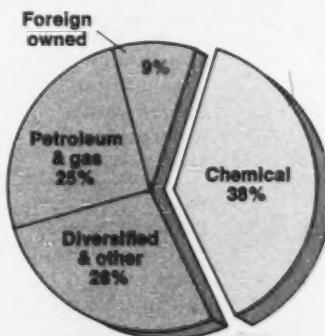


1986 sales = \$128 billion

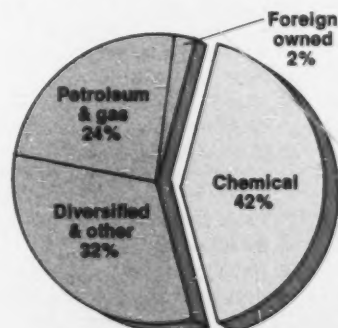


1986 operating profits = \$13.9 billion

...and chemical firms lead other types of producers



1986 sales = \$128 billion



1986 operating profits = \$13.9 billion

Restructurings continue to change Top 100 sales rankings

Rank 1986 1985		Chemical sales 1986 (\$ millions)	Change from 1985	Chemical sales as % of total sales	Industry classification	Chemical operating profits ^a (\$ millions)	Change from 1985	Chemical operating profits as % of total operating profits	Operating profit margin ^b	Identifiable chemical assets (\$ millions)	Chemical assets as % of total assets	Operating return on chemical assets ^c
1	1 Du Pont	\$11,839	5.2%	43.6%	Diversified	\$1764	102.8%	52.1%	14.9%	\$8739	36.2%	20.2%
2	2 Dow Chemical	8,863	-6.8	79.8	Basic chemicals	978	138.0	76.1	11.0	8139	66.5	12.0
3	3 Exxon	6,079	-8.9	8.1	Petroleum	817	112.2	9.9	13.4	5508	7.9	14.8
4	5 Union Carbide	5,001	26.3	75.8	Basic chemicals	748	81.1	94.6	15.0	5047	74.3	14.8
5	6 Atlantic Richfield	4,915	29.2	32.8	Petroleum	398	445.2	64.7	8.1	2085	9.7	19.1
6	4 Monsanto	4,701 ^d	-9.6	58.3	Basic chemicals	896	87.8	141.1	19.1	3860	46.7	23.2
7	12 BASF	3,600 ^d	38.5	100.0	Basic chemicals	na	na	na	na	na	na	na
8	7 Shell Oil	3,292	-0.8	19.6	Petroleum	646	292.7	35.1	19.7	3447	13.1	18.8
9	9 Amoco	2,928	0.8	14.5	Petroleum	467	-1.3	23.0	15.9	2545	11.0	18.3
10	8 Celanese	2,891	-5.1	100.0	Basic chemicals	258	103.1	100.0	8.9	na	na	na
11	17 Allied-Signal	2,819	37.2	23.9	Diversified	346	77.4	32.9	12.3	2161	19.2	16.0
12	10 W. R. Grace	2,492	-13.1	66.9	Specialty chemicals	285	21.8	1187.5	11.4	1633	53.1	17.5
13	13 Eastman Kodak	2,379	1.3	20.6	Photo equipment	227	24.0	31.4	9.5	2266	17.6	10.0
14	11 Chevron	2,378	-8.9	9.1	Petroleum	147	def	20.6	6.2	3207	9.3	4.6
15	15 Mobil	2,351	3.8	3.9	Petroleum	57	-29.6	1.1	2.4	2021	5.4	2.8
16	14 General Electric	2,331	-0.7	6.3	Diversified	424	-9.0	9.8	18.2	3602	10.4	11.8
17	22 Occidental Petroleum	2,088 ^e	28.8	13.0	Petroleum	176	75.1	36.2	8.4	2393	13.7	7.3
18	18 Rohm & Haas	2,067	5.1	100.0	Basic chemicals	280	3.7	100.0	13.5	1470	100.0	19.0
19	19 American Cyanamid	1,821	-0.5	47.7	Basic chemicals	135	66.8	38.3	7.4	1275	49.6	10.6
20	21 Air Products ^f	1,798	7.4	90.7	Basic chemicals	363	16.2	129.4	20.2	2173	80.3	16.7
21	23 Mobay	1,710	6.9	100.0	Basic chemicals	190	-6.4	100.0	11.3	1246	100.0	16
22	20 Hercules	1,709	-2.0	65.4	Basic chemicals	101	114.9	49.5	5.9	1484	71.6	6.9
23	15 Phillips Petroleum	1,698	-25.1	17.0	Petroleum	299	36.5	30.3	17.6	1053	8.5	28.4
24	25 Borden	1,638	7.0	32.7	Dairy products	176	36.4	35.3	10.7	1399	40.3	12.6
25	24 Ciba-Gelgy	1,490	-3.2	61.3	Specialty chemicals	na	na	na	na	na	na	na
26	26 Ashland Oil	1,477	-1.5	20.3	Petroleum	71	4.4	15.0	4.8	527	13.9	13.5
27	27 B. F. Goodrich	1,458	5.4	57.1	Rubber products	134	68.5	79.9	9.2	1199	82.5	11.1
28	29 FMC	1,399	11.0	46.6	Machinery	224	56.8	71.6	16.0	1344	50.0	16.7
29	28 American Hoechst	1,331 ^d	-2.2	77.8	Basic chemicals	na	na	na	na	na	na	na
30	31 Texaco	1,279	4.8	4.0	Petroleum	91	658.3	3.9	7.1	1114	3.2	8.2
31	30 Ethyl	1,272	2.5	57.0	Basic chemicals	247	24.8	69.0	19.4	829	48.4	29.8
32	34 Olin	1,114	-2.9	65.3	Basic chemicals	80	72.7	50.3	7.2	840	59.6	9.5
33	37 National Distillers	1,087	4.7	62.8	Alcoholic beverages	124	72.6	67.0	11.4	1385	47.7	8.9
34	40 Dow Corning	1,085	20.4	100.0	Specialty chemicals	111 ^g	16.2	100.0	10.2	na	na	na
35	36 International Minerals ^h	1,077	1.9	67.1	Agrochemicals	35	-74.2	57.1	3.2	2042	84.1	1.7
36	41 National Starch	1,064	20.7	100.0	Specialty chemicals	140	22.4	100.0	13.2	743	100.0	18.9
37	32 Unocal	1,058	-13.2	12.6	Petroleum	46 ^o	-20.7	26.1	4.4	722	7.1	6.4
38	38 Borg-Warner	1,043	12.3	30.9	Auto equipment	153	25.3	43.8	14.7	562	23.6	27.3
39	44 Lubrizol	889	10.6	91.0	Specialty chemicals	140	49.5	108.6	15.7	589	67.1	23.7
40	42 PPG Industries	843 ^o	0.2	18.0	Glass products	103	28.3	14.8	12.2	1185	25.5	8.7
41	85 Aluminum Co. of America	840 ^d	209.6	18.0	Nonferrous metals	na	na	na	na	na	na	na
42	51 Pennwalt	777	14.2	70.1	Basic chemicals	93	57.3	78.8	12.0	649	73.8	14.3
43	49 Cabot ⁱ	769	7.9	58.7	Specialty metals	138	55.9	69.3	17.9	494	32.7	27.9
44	39 CF Industries	766	-16.8	100.0	Agrochemicals	-45	def	def	def	842	100.0	def
44	43 Reichhold Chemicals	766	-6.9	100.0	Basic chemicals	53	150.7	100.0	7.0	458	100.0	11.6
46	— Aristech	751	-4.9	100.0	Steel	98	131.5	100.0	13.0	na	na	na
47	50 Nalco Chemical	736	7.9	100.0	Specialty chemicals	108	-11.0	100.0	14.7	586	100.0	18.4
48	58 NL Industries	734	30.1	57.2	Petroleum services	na	na	na	na	na	na	na
49	48 Eli Lilly	699	-2.0	18.8	Drugs	53	-39.8	5.8	7.6	766	16.7	6.9
50	54 Engelhard	686	11.3	29.1	Specialty metals	77	24.2	80.5	11.6	607	58.2	12.7

Rank 1986 1985	Chemical sales 1986 (\$ millions)	Change from 1985	Chemical sales as % of total sales	Industry classification	Chemical operating profits ^a (\$ millions)	Change from 1985	Chemical operating profits as % of total operating profits	Operating profit margin ^b	Identifiable chemical assets (\$ millions)	Chemical assets as % of total assets	Operating return on chemical assets ^c
51 53 Morton Thiokol ^b	\$652	5.8%	33.4%	Diversified	\$ 87	-2.6%	33.9%	13.4%	\$580	43.1%	15.1%
52 56 Terra Chemicals	626	9.0	100.0	Agrochemicals	na	na	na	na	na	na	na
53 64 International Flavors	621	23.9	100.0	Specialty chemicals	144	22.8	100.0	23.3	673	100.0	21.5
54 45 Williams Cos.	613	-17.4	33.0	Agrochemicals	na	na	na	na	na	na	na
55 52 Koppers	589	-4.8	42.2	Diversified	40	def	25.9	6.7	342	33.6	11.6
56 47 Farmland Industries	574	-20.4	21.1	Agricultural supplies	-38	def	def	def	342	45.8	def
57 — Huntsman Chemical	570	na	100.0	Basic chemicals	na	na	na	na	na	na	na
58 61 Vista Chemicals ^d	550	5.5	100.0	Basic chemicals	91	na	100.0	16.5	na	na	na
58 62 Solvay America	550	6.6	100.0	Basic chemicals	na	na	na	na	na	na	na
60 56 Witco	544 ^e	-5.2	40.1	Specialty chemicals	45	-21.3	34.0	8.2	275	33.6	16.2
61 63 Polysar	536	4.4	100.0	Basic chemicals	na	na	na	na	na	na	na
62 67 H. B. Fuller ^f	528	15.5	100.0	Specialty chemicals	39	26.5	100.0	7.5	291	100.0	13.6
63 66 Liquid Air	491	6.9	86.0	Basic chemicals	59	2.2	97.5	12.0	595	83.0	9.9
64 59 Standard Oil	475	-13.9	4.7	Petroleum	11	-59.3	1.5	2.3	347	2.2	3.2
65 65 Kerr-McGee	456	-5.7	18.0	Petroleum	14	-69.6	54.4	3.1	na	na	na
66 — CBI Industries	451	2.6	39.0	Construction	60	-4.5	95.9	13.3	552	47.3	10.9
67 71 American Petrofina	441	9.0	22.5	Petroleum	53	358.4	def	12.0	250	14.5	21.3
68 — Henley Group	435	14.5	13.7	Basic chemicals	60	def	def	13.6	359	7.6	16.7
69 74 Pfizer	416	6.0	9.3	Drugs	41	137.4	4.0	9.8	439	8.5	9.2
70 75 Tyler	386	3.4	40.4	Diversified chemicals	27	-8.9	51.1	7.0	187	37.2	14.5
71 73 Rhône-Poulenc	380	-5.0	100.0	Specialty chemicals	na	na	na	na	na	na	na
72 76 GAF	378	3.6	50.1	Specialty chemicals	108	16.4	77.5	28.6	252	18.7	42.8
73 68 Freeport-McMoRan	374	-17.1	59.4	Agrochemicals	76	-26.2	def	20.2	244	10.3	31.0
74 69 Merck	359	-20.3	8.7	Drugs	50	-14.4	4.8	13.9	431	11.7	11.6
75 79 Betz Laboratories	344	7.8	100.0	Specialty chemicals	63	4.6	100.0	18.4	270	100.0	23.5
76 72 Sun Co.	317	-21.1	3.0	Petroleum	na	na	na	na	na	na	na
77 77 Chemed	314	-6.6	87.4	Specialty chemicals	33	-23.8	82.7	10.5	162	82.6	20.3
78 84 Union Camp	305	10.9	14.9	Diversified	6	-30.3	2.6	2.0	227	8.3	2.7
79 83 Great Lakes Chemical	300	6.5	100.0	Specialty chemicals	43	-5.9	100.0	14.2	na	na	na
80 86 Ferro	286 ^g	6.8	39.4	Specialty materials	22	62.0	37.4	7.8	162	41.4	13.7
81 90 Loctite	267	15.3	100.0	Specialty chemicals	37	5.5	100.0	13.8	244	100.0	15.1
82 — Henkel	265	-8.0	100.0	Specialty chemicals	na	na	na	na	na	na	na
83 89 Stepan	260	10.1	100.0	Specialty chemicals	14	51.7	100.0	5.4	153	100.0	9.2
84 88 Kaiser Aluminum	254	-0.1	11.5	Nonferrous metals	34	333.3	60.0	13.3	284	8.8	11.9
84 81 Petrolite ^h	254	-12.5	90.7	Specialty chemicals	23	-36.8	94.6	9.0	158	68.8	14.4
84 80 Vulcan Materials	254	-13.2	26.5	Nonmetallic minerals	19	-19.9	12.1	7.7	na	na	na
87 91 Lonza	252	27.9	100.0	Specialty chemicals	na	na	na	na	na	na	na
88 82 Dexter	245	-12.9	37.6	Rubber products	23	-17.4	30.3	9.5	162	62.6	14.4
89 78 Mississippi Chemical ^b	228	-30.0	100.0	Farm cooperative	-13	def	def	def	265	100.0	def
90 95 Sigma-Aldrich	199	20.9	76.8	Specialty chemicals	53	11.5	84.4	26.4	207	84.4	25.5
91 93 Essex Chemical	184	6.8	89.4	Basic chemicals	32	0.0	115.3	17.4	105	76.3	30.5
92 99 Crompton & Knowles	165	46.1	77.2	Specialty chemicals	15	19.4	65.1	9.0	94	83.5	15.8
93 92 Georgia-Pacific	155	-10.4	2.1	Wood products	na	na	na	na	na	na	na
94 97 First Mississippi	153	1.2	56.6	Agrochemicals	20	-36.3	def	13.0	67	26.1	29.6
95 96 Agway	143	-11.6	4.1	Farm cooperative	na	na	na	na	na	na	na
96 — Quaker Chemical	128	4.4	100.0	Specialty chemicals	14	11.3	100.0	10.8	99	100.0	14.0
97 98 UGI	113	-3.9	25.4	Natural gas	0	def	def	def	168	28.8	def
98 — LeaRonai	105	-19.5	100.0	Specialty chemicals	10	-26.1	100.0	9.8	65	100.0	15.8
99 100 Lawter Chemicals	104	7.0	100.0	Diversified	20	49.0	100.0	19.0	93	100.0	21.1
100 — Products Research & Chemical	83	10.4	90.2	Specialty chemicals	16	18.3	62.9	18.7	53	82.7	29.5

^a Operating profit is sales less administrative expenses and cost of sales. ^b Operating profit from chemicals as a percentage of chemical sales. ^c Chemical operating profit as a percentage of identifiable chemical assets. ^d Chemical sales include significant amounts of nonchemical products. ^e Does not include all chemical sales. ^f Fiscal year ends Sept. 30. ^g Chemical net profits. ^h Fiscal year ends June 30. ⁱ Fiscal year ends Nov. 30. ^j Fiscal year ends Oct. 31. na = not available. def = deficit.

C&EN's five-way ranking of the Top 100 chemical producers

	Chemical sales			Chemical operating profits			Chemical operating profit margin			Identifiable chemical assets			Return on chemical assets		
	Rank			Rank			Rank			Rank			Rank		
	1986	1985	1984	1986	1985	1984	1986	1985	1984	1986	1985	1984	1986	1985	1984
\$ Millions															
Agway	\$ 143	95	96	na	—	—	na	—	—	na	—	—	na	—	—
Air Products	1,798	20	21	\$ 363	9	8	20.2%	4	10	\$2173	12	16	16.7%	28	24
Allied-Signal	2,819	11	17	346	10	13	12.3	36	39	2161	13	15	16.0	30	44
Aluminum Co. of America	840	41	85	na	—	—	na	—	—	na	—	—	na	—	—
American Cyanamid	1,821	19	19	135	27	34	7.4	63	64	1275	23	25	10.6	56	57
American Hoechst	1,331	29	28	na	—	—	na	—	—	na	—	—	na	—	—
American Petrofina	441	67	71	53	46	71	12.0	38	73	250	59	61	21.3	15	69
Amoco	2,926	9	9	467	7	3	15.9	18	15	2545	9	10	18.3	24	15
Aristech	751	46	—	98	34	—	13.0	34	—	na	—	—	na	—	—
Ashland Oil	1,477	26	26	71	42	40	4.8	72	63	527	44	50	13.5	45	32
Atlantic Richfield	4,915	5	8	na	—	—	na	—	—	2085	14	11	19.1	19	—
BASF	3,600	7	12	na	—	—	na	—	—	na	—	—	na	—	—
Betz Laboratories	344	75	79	63	43	43	18.4	11	9	270	56	64	23.5	12	10
Borden	1,638	24	25	176	19	19	10.7	47	44	1399	20	21	12.6	47	46
Borg-Warner	1,043	36	36	153	21	22	14.7	22	22	562	42	54	27.3	9	7
Cabot	769	43	49	138	26	32	17.9	13	27	494	45	52	27.9	8	19
CBI Industries	451	66	—	60	44	—	13.3	31	—	552	43	—	10.9	55	—
Celanese	2,891	10	8	258	14	20	8.9	56	67	na	—	9	na	—	63
CF Industries	766	44	39	45	82	80	def	—	—	842	29	30	def	—	—
Chemed	314	77	77	33	62	55	10.5	48	24	162	66	72	20.3	17	8
Chevron	2,378	14	11	147	22	84	6.2	69	—	3207	8	8	4.6	69	—
Ciba-Gelgy	1,490	25	24	na	—	—	na	—	—	na	—	—	na	—	—
Crompton & Knowles	165	92	99	15	72	71	9.0	54	32	94	73	81	15.8	31	20
Dexter	245	88	82	23	65	63	9.5	51	35	162	66	74	14.4	39	17
Dow Chemical	8,863	2	2	978	2	6	11.0	45	66	8139	2	1	12.0	48	61
Dow Corning	1,085	34	40	na	—	—	na	—	—	na	—	—	na	—	—
Du Pont	11,839	1	1	1,764	1	1	14.9	21	49	8739	1	2	20.2	18	40
Eastman Kodak	2,379	13	13	227	16	14	9.5	51	48	2266	11	12	10.0	57	50
Eli Lilly	699	49	48	53	48	32	7.6	61	27	766	32	32	6.9	66	41
Engelhard	666	50	54	77	40	42	11.6	41	33	607	37	49	12.7	46	36
Essex Chemical	184	91	93	32	63	59	17.4	15	10	105	71	79	30.5	3	4
Ethyl	1,272	31	30	247	15	12	19.4	7	16	829	31	35	29.8	4	9
Exxon	6,079	3	3	817	4	7	13.4	29	58	5508	3	3	14.8	36	53
Farmland Industries	574	56	47	38	81	77	def	—	78	342	51	55	def	—	75
Ferro	286	80	86	22	67	69	7.8	59	59	162	66	75	13.7	43	46
First Mississippi	153	94	97	20	68	60	13.0	34	7	67	75	82	29.6	5	2
FMC	1,399	28	29	224	17	17	16.0	17	31	1344	22	24	16.7	26	38
Freeport-McMoRan	374	73	68	76	41	26	20.2	4	5	244	60	68	31.0	2	1
H. B. Fuller	528	62	67	39	58	57	7.5	62	53	291	53	65	13.6	44	33
GAF	376	72	76	108	30	29	28.6	1	2	252	58	67	42.6	1	3
General Electric	2,331	16	14	424	8	4	18.2	12	8	3602	6	7	11.8	50	35
Georgia-Pacific	155	93	92	na	—	—	na	—	—	na	—	—	na	—	—
B. F. Goodrich	1,456	27	27	134	28	37	9.2	53	57	1199	25	27	11.1	54	55
W. R. Grace	2,492	12	10	285	12	10	11.4	42	46	1633	17	14	17.5	25	36
Great Lakes Chemical	300	79	83	43	55	54	14.2	24	14	na	—	—	na	—	—
Henkel	265	62	—	na	—	—	na	—	—	na	—	—	na	—	—
Henley Group	435	68	—	60	44	—	13.8	26	—	359	49	—	16.7	26	—
Hercules	1,709	22	20	101	33	50	5.9	70	74	1464	19	19	6.9	66	71
Huntsman Chemical	570	57	—	na	—	—	na	—	—	na	—	—	na	—	—
International Flavors	621	53	64	144	23	25	23.3	3	4	673	35	44	21.5	14	14

\$ Millions	Chemical sales			Chemical operating profits			Chemical operating profit margin			Identifiable chemical assets			Return on chemical assets		
	Rank			Rank			Rank			Rank			Rank		
	1986	1985	1984	1986	1985	1984	1986	1985	1984	1986	1985	1984	1986	1985	1984
International Minerals	\$1,077	35	34	\$ 35	60	18	3.2%	74	25	\$2042	15	23	1.7%	73	42
Kaiser Aluminum	254	84	88	34	61	76	13.3	31	72	284	54	62	11.9	49	72
Kerr-McGee	456	65	65	14	73	50	3.1	75	37	na	—	43	na	—	51
Koppers	589	55	52	40	57	83	6.7	68	—	342	51	58	11.6	51	—
Lawler International	104	99	100	20	68	70	19.0	9	19	93	74	80	21.1	16	27
LeaRonai	105	98	—	10	77	—	9.8	49	—	65	76	—	15.8	31	—
Liquid Air	491	63	66	59	46	46	12.0	38	28	595	38	—	9.9	58	—
Locliffe	267	81	90	37	59	57	13.8	26	17	244	60	66	15.1	34	25
Lonza	252	87	91	na	—	—	na	—	—	na	—	—	na	—	—
Lubrizol	889	39	44	140	24	29	15.7	19	30	589	39	39	23.7	11	28
Merck	359	74	69	50	52	46	13.9	25	23	431	48	59	11.6	51	26
Mississippi Chemical	228	89	78	—13	80	77	def	—	77	265	57	60	def	—	74
Mobay	1,710	21	23	193	18	16	11.3	44	41	1246	24	26	15.4	33	34
Mobil	2,351	15	15	57	47	34	2.4	76	70	2021	16	13	2.8	71	68
Monsanto	4,701	6	4	896	3	2	19.1	8	42	3860	5	5	23.2	13	39
Morton Thiokol	652	51	53	87	38	31	13.4	29	18	580	41	47	15.1	34	23
Nalco Chemical	736	47	50	108	30	22	14.7	22	12	586	40	48	18.4	23	11
National Distillers	1,087	33	35	124	29	39	11.4	42	52	1385	21	36	8.9	62	46
National Starch	1,064	36	41	140	24	41	13.2	33	50	743	33	37	18.9	21	43
NL Industries	734	48	58	na	—	20	na	—	6	na	—	57	na	—	5
Occidental Petroleum	2,088	17	22	176	19	28	8.4	57	54	2393	10	18	7.3	65	58
Olin	1,114	32	33	80	39	53	7.2	64	68	840	30	31	9.5	59	60
Pennwalt	777	42	51	93	35	45	12.0	38	43	649	36	38	14.3	41	45
Petrolite	254	84	81	23	65	56	9.0	54	27	158	69	71	14.4	39	13
Pfizer	416	69	74	41	56	68	9.8	49	64	439	47	56	9.2	60	64
Phillips Petroleum	1,698	23	15	299	11	11	17.6	14	37	1053	28	22	28.4	7	22
Polysar	536	61	63	na	—	—	na	—	—	na	—	—	na	—	—
PPG Industries	843	40	42	103	32	36	12.2	37	39	1185	26	28	8.7	63	54
Products Research & Chemical	83	100	—	16	71	—	18.7	10	—	53	77	—	29.5	6	—
Quaker Chemical	128	96	—	14	73	—	10.8	46	—	99	72	—	14.0	42	—
Reichhold Chemicals	786	44	43	53	48	66	7.0	66	75	458	46	51	11.6	51	64
Rhône-Poulenc	380	71	73	na	—	—	na	—	—	na	—	—	na	—	—
Rohm & Haas	2,067	18	18	280	13	9	13.5	28	19	1470	18	20	19.0	20	16
Shell Oil	3,292	8	7	648	6	15	19.7	6	80	3447	7	6	18.8	22	67
Sigma-Aldrich	199	90	95	53	48	50	26.4	2	1	207	63	73	25.5	10	6
Solvay America	550	58	62	na	—	—	na	—	—	na	—	—	na	—	—
Standard Oil	475	64	59	11	76	64	2.3	77	61	347	50	46	3.2	70	62
Stepan	260	83	89	14	73	74	5.4	71	69	153	70	76	9.2	60	56
Sun Co.	317	76	72	na	—	—	na	—	—	na	—	—	na	—	—
Terra Chemicals	626	52	56	na	—	—	na	—	—	na	—	—	na	—	—
Texaco	1,279	30	31	91	36	71	7.1	65	76	1114	27	29	8.2	64	73
Tyler	388	70	75	27	64	62	7.0	66	47	187	64	70	14.5	38	21
UGI	113	97	98	0	79	79	def	—	79	168	65	77	def	—	76
Union Carbide	305	78	84	6	78	74	2.0	78	71	227	62	69	2.7	72	64
Union Carbide	5,001	4	5	748	5	5	15.0	20	33	5047	4	4	14.8	36	49
Unocal	1,058	37	32	46	53	46	4.4	73	82	722	34	34	6.4	68	52
Vista Chemical	550	58	61	91	37	—	10.5	16	—	na	—	—	na	—	—
Vulcan Materials	254	84	80	19	70	65	7.7	60	45	na	—	—	na	—	—
Williams Cos.	613	54	45	na	—	62	na	—	—	na	—	45	na	—	—
Witco	544	60	58	45	54	49	6.2	56	36	275	55	63	16.2	29	12

Note: Companies with negative profitability and those giving only net profits are not ranked. There are 82 firms ranked for operating profits, 78 for operating profit margin, 77 for chemical assets, and 73 for return on assets for 1986. na = not available. def = deficit.

closed down businesses. However, the three largest chemical producers—Du Pont, Dow Chemical, and Exxon—remained first, second, and third, respectively; beyond that, companies began to shift positions. Union Carbide, which had ranked fifth in 1985, moved up to fourth, a rank it has not held since 1981. And Atlantic Richfield rose to fifth place from sixth in 1985. Monsanto, which had ranked fourth from 1985 chemical sales, dropped to sixth in 1986 as the company sold off some of its chemical operations.

BASF Corp., the U.S. arm of West Germany's BASF, rose to seventh place from 12th in 1985 as results from recently acquired companies such as Enka and Inmont began to be felt. Shell Oil, however, fell to eighth place from ninth, partly owing to divestiture. Amoco remained in ninth place, the same as in 1985, and Celanese dropped to 10th place from eighth the year before. For the 1986 ranking, Celanese and American Hoechst are treated as separate companies since they were independent throughout the entire year (but merged at the beginning of this year).

As in each year's Top 100 ranking, companies in the 1986 list are compared with what their rankings were one year ago rather than what they would have been based on restated results in the current year annual report. Thus, a rise or fall in rank may well reflect acquired or divested chemical businesses during the year as well as increasing or decreasing sales from operations.

Eight companies are new to the list this year. The largest of these is Aristech at 46th place. This is the former chemical operations of USX Corp. that were spun off last year and formed into a separate publicly traded company. Huntsman Chemical, also new at 57th place, has as its core the former styrenics business of American Hoechst. CBI Industries, which is ranked 66th, has as its chemical operations the Liquid Carbonics industrial gas business, acquired from Enron, which has been removed from the list because it no longer is a chemical producer.

Henkel Corp., in 82nd place, is not new to the list but reappears after being off the rankings for 1985

when it did not break out its U.S. sales. Three companies, Quaker Chemical at 96th, LeaRonald at 98th, and Products Research & Chemical at 100th, have moved onto the list as a result of sales growth and other companies' having dropped off the list because of divested chemical operations.

Besides Enron, other companies that have dropped off the Top 100 listing this year are Big Three Industries, acquired by Liquid Air; Chesebrough-Pond's, acquired by Unilever; Emhart, which has reorganized and no longer breaks out chemical sales in its annual report (efforts to reach the company were unsuccessful); Millmaster Onyx, which has sold its operations in a leveraged buyout; SCM, acquired by Hanson Trust; USX Corp., which spun off its chemical operations to form Aristech; and Williams Cos., which has sold its Agrico fertilizer operations to Freeport-McMoRan.

As usual, some companies that have large chemical operations do not appear on the list. Some of the more outstanding examples are such U.S.-based firms as 3M and Procter & Gamble; privately held companies such as J. M. Huber; and foreign-owned companies with U.S. operations such as Imperial Chemical Industries' ICI Americas and Schering A.G.'s Sherex Chemical.

The rankings of the largest chemical producers remain less precise than desired, because C&EN must by and large rely on the data supplied by the companies themselves, and the definition of what is a chemical or where to include chemical operations varies widely from company to company. Those data can include nonchemical operations in some firms such as Monsanto, Aluminum Co. of America, and BASF Corp. Other firms, such as Witco, PPG Industries, and Occidental Petroleum, have significant chemical operations that are hidden within divisions other than those that they decide to call chemical.

Besides the sales rankings, C&EN rates the 100 largest chemical producers four other ways, by chemical operating profits, operating profit margin (chemical operating profits as a percentage of chemical sales), identifiable chemical assets, and re-

turn on chemical assets (chemical operating profits as a percentage of identifiable chemical assets).

As in chemical sales (\$11.8 billion in 1986), Du Pont was number one in chemical operating profits with a total of \$1.76 billion. Dow Chemical ranks second with \$978 million in chemical operating profits, up from sixth place in 1985. Monsanto, at third with \$896 million, dropped from second in 1985. Fourth-place Exxon had chemical operating profits of \$817 million and was up from seventh in 1985. And Union Carbide, with chemical operating profits of \$748 million, was fifth, the same as in 1985.

The top-ranking company for chemical operating profit margin was GAF, with a return of 28.6%, up from second in 1985. Sigma-Aldrich ranked second with a return of 26.4%; it fell from first place in 1985. Ranked third is International Flavors & Fragrances with a return of 23.3%. IFF held fourth place the year before. Air Products and Freeport-McMoRan tied for fourth place with an operating profit margin of 20.2%. In 1985, Air Products had ranked 10th and Freeport had been fifth.

Du Pont ranked first in identifiable chemical assets with \$8.74 billion, and Dow ranked second with \$8.14 billion. This is a reversal of their rankings in 1985. Exxon ranked third with \$5.51 billion, the same rank as the previous year. Fourth, and the same rank as in 1985, was Union Carbide at \$5.05 billion. And Monsanto was fifth with identifiable chemical assets of \$3.86 billion. Monsanto also had been fifth the previous year.

As with operating profit margin, GAF ranked first in return on identifiable chemical assets with 42.8%. This is up from third in 1985. Freeport-McMoRan ranked second with a return of 31.0%. In 1985, Freeport had been first. Essex Chemical ranked third, up from fourth in last year's ranking, with its return on chemical assets of 30.5%. Ethyl ranked fourth with a return of 29.8%, and was up from ninth place in 1985. And in fifth place was First Mississippi, with a return on chemical assets of 29.6%. In 1985, First Mississippi had ranked second. □

Rise in atmospheric methane probed

Systematic global measurements have firmly established that the concentration of methane in the atmosphere is increasing about 1% per year. Last month at the American Chemical Society meeting in Denver, an interdisciplinary group of scientists gathered to try to understand why.

Pinning down responsibility for the increase is a difficult problem, as methane is formed both by thermocatalytic reactions in Earth's crust and by many bacteria. Scientists working in atmospheric chemistry, microbiology, biogeochemistry, stable-isotope chemistry, and radiocarbon dating met and exchanged ideas at a five-day symposium sponsored by the Division of Geochemistry. Researchers from the various disciplines aimed to give each other an appreciation of the possibilities and limitations of the various approaches to the complex problem, according to symposium organizer Ronald S. Oremland, a microbial geochemist with the U.S. Geological Survey.

The increase in methane is a concern because methane is a greenhouse gas that traps infrared radiation emitted by Earth's surface. Climate models predict the accumulation of methane and other greenhouse gases like carbon dioxide and chlorofluorocarbons is leading inexorably to a global warming. On a molecule-per-molecule basis, methane is a more important greenhouse gas than carbon dioxide, says F. Sherwood Rowland, professor of chemistry at the University of California, Irvine. That's so, he says, because methane is 20 times more efficient at trapping infrared radiation.

Rowland's research group has been measuring methane and other trace gases in the atmosphere over a wide range of latitudes since 1978. "The average concentration at the beginning of 1987 was 1.68 ppm, about 10% higher than when we began taking measurements," says Irvine chemist Donald R. Blake—an average increase of about 1% per year.

That rate of increase has been fairly steady for almost 200 years, according to M. Aslam K. Khalil, a physicist with the Oregon Graduate Center's Institute of Atmospheric Sciences in Beaverton. Analysis of air samples trapped in polar ice cores shows that from about 4000 years ago until 200 years ago, methane concentrations hovered around 700 ppb. Khalil and his collaborator, Reinhold A. Rasmussen, also at the Oregon Graduate Center, think that about half of the annual emissions are from natural sources. The other half are related to agricultural and industrial sources that have been increasing as the world's population has increased.

Oil and gas exploitation is one source of methane that is related to human activity. Studies of the carbon-14 content of atmospheric methane, however, indicate that at least 80% must have a biological, as opposed to fossil fuel, origin.

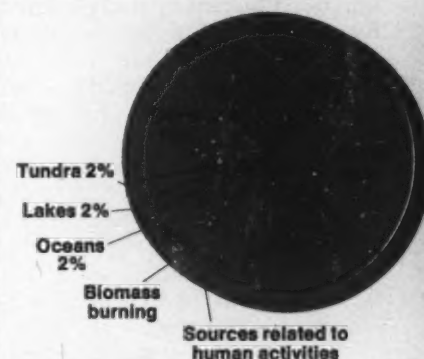
Bacteria produce methane by anaerobic fermentation in wet locations where oxygen is scarce: peat bogs, swamps, other natural wetlands, paddies, and the intestinal tracts of cattle and termites. The number of cattle in the world has increased from about 800 million in 1950 to about 1.3 billion today, Khalil notes. He also points out that multiple cropping of rice has become more common, so paddies are flooded for a greater part of the year than they once were.

The increase in methane also may be caused in part by rising levels of carbon monoxide from combustion processes. Both methane and carbon monoxide are removed from the atmosphere largely by reaction with hydroxyl radicals. With both gases competing for a limited amount of hydroxyl, the average lifetime of methane molecules before they are destroyed may be getting longer.

"We need more work on the important details of the sources, sinks, and atmospheric chemistry of methane," says Khalil. "Better assignments of contributions from individual sources and the distribution of those sources globally will let us make better projections for the future."

Among many projects aimed at just those goals that were described

Wetlands and paddies yield almost half of all methane



Sources: M. A. K. Khalil and R. A. Rasmussen, Oregon Graduate Center, Beaverton

at the symposium are experiments that use the $^{13}\text{C}/^{12}\text{C}$ isotope ratio of methane to try to ascertain where the gas is coming from. Atmospheric scientist Stanley C. Tyler and his coworkers at the National Center for Atmospheric Research in Boulder are measuring the stable isotope content of methane from different sources.

Using an isotope-ratio mass spectrometer, they find the isotope ratio of methane varies with its source. For example, Tyler finds that methane collected from termite mounds contains from 54 to 58 parts per thousand less carbon-13 than a reference standard of carbonate rock. Methane collected from swamps and marshes in temperate and tropical locations contains from 48 to 69 parts per thousand less carbon-13 than the standard. However, atmospheric methane on the average is depleted in carbon-13 by about 47 parts per thousand. The researchers are trying to come up with a weighted sum of values from the various sources and sinks that will equal the average $^{13}\text{C}/^{12}\text{C}$ ratio of atmospheric methane.

"One good thing about isotope ratios is they will help us understand the mechanism of consumption and production of methane," says Tyler. "We now have ballpark figures for a lot of sources. We need to characterize a few areas in depth, so then we can extrapolate to other areas with similar environmental conditions."

Pamela Zurer, Washington